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Electrical properties of molybdenite

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Of the investigations carried out to study the electrical properties of natural single crystals of molybdenite (MoS_2) special mention may be made of those by Gottstein (1914), Dey (1944), Dutta (1947), Mansfield & Salam (1953) and Evans & Young (1965). But none of these measurements is complete in the sense that both the principal values of all the required electrical properties have not been determined over the necessary temperature range. Further, these workers do not agree as to the sign of the carriers, as also to some extent the values and the nature of the temperature variations of the different electrical properties (table 1). We have, therefore, undertaken to measure in vacuum and in dark the principal values of electrical conductivities and of thermoelectric powers. The Hall effect could, however, be measured only for currents in the basal plane, measurement with current in the other direction not being possible, due to the peculiar flaky nature of the crystal. A number of natural molybdenite crystals usedobtained from Ceylon, was used for these measurements extending over the temperature range from 90°K to about 840°K. Results of these measutements on a typical crystal are shown in table 1 and figures 1, 2 and 3.

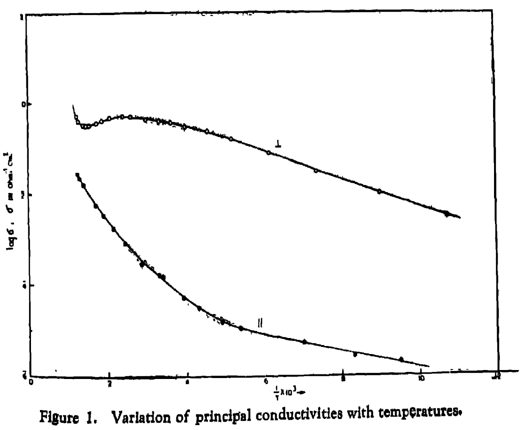

Figure 1. Variation of principal conductivities with temperatures.

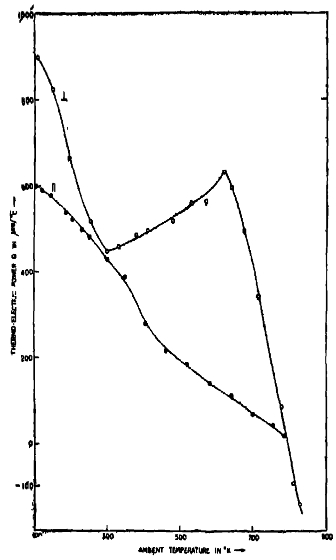

Figure 2. Variation of principal thermoelectric powers with temperatures.

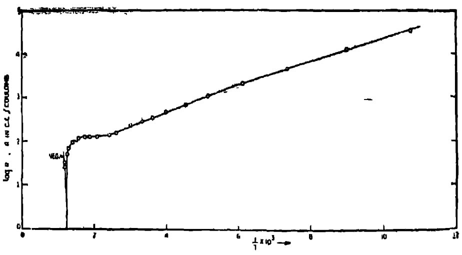

Figure 3. Variation of Hall coefficient with temperatures.

For directions in the basal plane molybdenite has been found to be a *p*-type semiconductor at lower temperatures changing to *n*-type in the

TABLE 1

Authors	Conductivities in Ohm^{-1} Cm^{-1}		Activation energy $E_{\perp}$ in ev. in the $\perp$ range of		Activation energy $E_{\parallel}$ in ev. in the $\parallel$ range of		Hall coeff. in c.g.s. e.m.u.	Thermolectric power Q in $\mu V/°C$ at 300°K	
	$\sigma_{\perp}$	$\sigma_{\parallel}$	impurity	intrinsic	impurity	intrinsic		$Q_{\perp}$	$Q_{\parallel}$
Gottstein	0.61 at 300°K	—	0.145	—	—	—	-1500 at 291°K	463 to 739	—
Dey	1.03 at 300°K	3.69×10^{-4}	0.09	—	0.12	—	—	—	—
Dutta	1.09 at 300°K	3.0×10^{-4}	0.0022	—	0.001	—	—	—	—
Mansfield & Salam	0.009 to 4.2 at room temperatures	—	0.09	—	—	—	350 to 30.000 at room temperatures	520 to 580	—
Evans & Young	0.078 at 290°K	4.6×10^{-4}	0.08	0.87	0.08	0.87	-2850 at 290°K	—	—
Present Author	0 79	3.88×10^{-4}	0.10	1.1	0.07	0.70	2880 at 300°K	450	430

intrinsic region at high temperature (about 800°K) as revealed by the reversal of sign of Hall coefficient and of thermoelectric power. But along the c-axis, though the actual reversal of sign of the thermoelectric power did not take place even upto 790°K, the value diminished in such a manner that an actual reversal at higher temperatures might be expected.

From a study of the conductivity curves (figure 1) and also in view of the above finding it may be inferred that at ordinary temperatures the $\sigma_{\perp}$, conductivity along the basal plane, is mainly due to the presence of an acceptor type of impurity level in the forbidden region (*P*-type conduction) which owing to a large band gap gets exhausted at higher temperatures and after that, till a temperature sufficient to overcome the energy gap between the valence and conduction band is attained, and then the number of carriers remains steady (shown by the usual type of fall of conductivity with rise of temperature due to lattice scattering). After that conductivity begins to rise again due to excitation of electrons from valence band to the conduction band. But the absence of a similar behaviour along the c-axis appears to be due to the electrons being excited to the conduction band simultaneously with the exhaustion of the impurity level indicating a smaller energy gap (in this direction). Such view is also supported from the consideration of the structure of the Brillouin zone in molybdenite.

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